Agricultural Applications Of Weather Derivatives

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ABSTRACT

Weather derivatives are currently a fast growing derivatives sector. The purpose of this article is to examine the background of the weather derivatives market and some of its benefits for agricultural risk management. In addition, this article is meant to serve as an overview of the benefits and uses of weather derivatives for those who may not be otherwise exposed to this type of market. This article examines the structure of Heating Degree Day and Cooling Degree Day contracts along with agricultural hedging uses of weather derivatives, notably, a use unique in this market, hedging of volumetric risk.

INTRODUCTION

The weather derivatives industry is relatively young. This derivatives sector began to develop in 1997, as a result of the severe weather events of El Niño. The El Niño events of 1996-1998 were the first such major climate forecasts that the meteorological community forecasted correctly. The El Niño winter of 1997-1998 was forecasted to be unseasonably mild. This caused numerous companies that had earnings tied to weather to realize the importance of hedging their seasonal weather risk. During this time, the insurance industry was in a position to make available a sufficient amount of capital to hedge weather risk. There were a large number of options with payouts tied to weather events that were written by insurance companies, which increased liquidity for the development of a monthly and seasonal market for weather derivatives. As a result of these events, the weather derivatives market grew rapidly into a thriving over-the-counter market (Considine, 2006). However, continued growth was limited due to the credit risk associated with an over-the-counter market.

To further increase the size of the weather derivatives market and to remove the counter-party credit risk involved in over-the-counter weather contracts, the Chicago Mercantile Exchange (CME) introduced the first exchange-traded, temperature-related weather futures and options on September 22, 1999. The CME contracts give large and small investors the opportunity to hedge their weather-related risks using liquid, standardized contracts with the additional benefit of having access to the best available prices at all times. A significant advantage of the CME's exchange-traded contracts is the presence of the CME Clearing House, which reduces counter-party credit risk by guaranteeing performance of both parties in a weather futures or options contract. The CME Clearing House acts as the buyer for every seller and the seller to each buyer, thus ensuring that each party honors their financial obligation.

The CME offers Heating Degree Day (HDD) and Cooling Degree Day (CDD) futures contracts and options on futures for monthly and seasonal temperature related events. HDD futures and options are traded on the fall and winter months of October through April, while CDD futures and options are traded on the spring and summer months of April through October. The futures contracts trade exclusively on the CME's Globex electronic trading system from 5:00 p.m. to 3:15 p.m. the following day, while the options trade on the CME trading floor from 8:30 a.m. to 3:15 p.m. The CME contracts are based on indexes of HDDs and CDDs and are traded on selected cities throughout the United States, Europe, and Asia-Pacific. These cities were chosen based upon their population, the unpredictability in their seasonal temperatures, and the number of contracts written in the over-the-counter market for each city. As of February 2006, the CME offers weather futures and option contracts for 18 cities in the United States, nine European cities, and the two Asia/Pacific cities (Chicago, 2006). The specific cities are listed in Table 1.

Table 1. Cities With CME Weather Derivatives

U.S. Cities		European Cities	Asia/Pacific Cities
Atlanta	Las Vegas	London	Tokyo
Chicago	Boston	Paris	Osaka
Cincinnati	Houston	Amsterdam	
New York	Kansas City	Berlin	
Dallas	Minneapolis	Essen	
Philadelphia	Sacramento	Stockholm	
Portland	Salt Lake City	Rome	
Tucson	Detroit	Madrid	
Des Moines	Baltimore	Barcelona	

Source: Chicago Mercantile Exchange, 2006.

As of February 2006, the CME's website notes that the exchange-traded weather derivatives market is currently the fastest growing derivatives sector. Given that this market is increasing in popularity, this article examines the background of the weather derivatives market and some of its benefits for agricultural risk management. In particular, this article is meant to serve as an overview of weather derivatives for those who may not be otherwise exposed to this type of market. The next section discusses degree days, the temperature standard that the prices of weather derivatives are based on, and the structure of HDD and CDD indexes. Section three examines hedging uses of weather futures and options. Section four notes unique aspects of weather derivatives, such as seasonal contracts and volumetric risk management, in addition to basis risk involved with exchange-traded weather contracts. Section five offers conclusions.

DEGREE DAY STANDARD

Much of the agricultural community is familiar with the general concept of degree days as used to calculate growing degree days (GDD). A GDD is an index used to convey the level of maturity of a given crop. A crop needs a specific number of GDD to reach maturity, no matter how many days are required to accumulate them. There are a number of benchmark temperatures from which GDD are calculated. The specific benchmark temperature depends on the crop. For example, the benchmark temperature used to calculate GDD for corn is 50 degrees Fahrenheit (National, 2006). The utility industry in the United States has found that 65 degrees Fahrenheit is a benchmark temperature to differentiate between transactions in the heating and cooling seasons. This standard came about because, in the past, individuals often turned on their furnaces when the temperature fell to 65 degrees. Consumers will burn more energy to heat their homes for each degree below 65 and will use more energy to run their air conditioners for each degree above 65.

Degree days used in weather derivatives are based on this 65 degree standard and are calculated as the difference in the daily average temperature from 65 degrees Fahrenheit. The daily average temperature is calculated by averaging each day's maximum and minimum temperature from midnight-to-midnight. A Heating Degree Day (HDD) is calculated by subtracting the daily average temperature from 65 degrees Fahrenheit. A Cooling Degree Day (CDD) is calculated by subtracting 65 degrees from the daily average temperature. There cannot be both heating and cooling degree days in a single day, given that the daily average temperature can only be either above or below 65 degrees. Thus, if the average daily temperature is less than 65 degrees, HDD will accumulate for the period, and if the average daily temperature is greater than 65 degrees, CDD will accumulate. HDD are best thought of in terms of needing to use the heater, and CDD are best thought of in terms of needing to use the air conditioner. Simply put, the formulas are as follows:

$$\text{Daily HDD} = \max\left[0, 65^{o} - \frac{\left(T_{\max} + T_{\min}\right)}{2}\right] \quad (1)$$

and

$$\text{Daily CDD} = \max\left[0, \frac{(T_{\max} + T_{\min})}{2} - 65^{o}\right] \quad (2)$$

To illustrate the concept of HDD and CDD, suppose that on a given winter day the high temperature was 41 degrees and the low temperature was 25 degrees. This weather results in a daily average temperature of 33 degrees with 32 HDD and no CDD for this day. Now suppose that on a given summer day the high was 92 degrees and the low was 78. The daily average temperature for this day would be 85 degrees with 20 CDD.

As an example of accumulation of degree days, suppose that for a month of March the daily average temperature was a mild 60 degrees for the entire first week. During the week, five HDD will accumulate for each day or a total of 35 HDD (5 HDD x 7) over the week. Now suppose the second week of the month is warmer, and there are seven days with daily average temperatures of 71 degrees each day. During this week, a total of 42 CDD (6 CDD x 7) will accumulate.

The CME's HDD and CDD futures and options contracts are based on indexes of HDD and CDD. These indexes are an accumulation of daily HDDs and CDDs, over a calendar month or an entire season. Each HDD or CDD in either index is valued at $20 for cash settlement of the contract. In the example above, after the first week of mild weather, the HDD index would be at 35 HDD. With an HDD index of 35, the nominal value of the HDD futures contract would be $700 (35 HDD Index x $20). Similarly, the cumulative value of the CDD index after the warmer week would be $840 (42 CDD Index x $20). Now, in the third week of the month, suppose there were four days with 6 HDD each and three days with 3 CDD each, the HDD index would now be 59 (35 HDD + 4 x 6 HDD) and worth $1,180 (59 HDD x $20), and the CDD index would now be 51 (42 CDD + 3 x 3 CDD) and would be valued at $1,020 (51 CDD x $20).

HEDGING WITH WEATHER DERIVATIVES

HDD and CDD futures and options have many uses for agricultural risk management. Companies in the agriculture industry, with revenues adversely affected by extremely hot summers or cold winters, can buy weather contracts and hedge lower revenues during extreme weather conditions. Conversely, companies, such as utilities, with revenues adversely affected by mild summers or mild winters can sell these contracts and hedge their lower revenues in such times.

Hedging With Weather Futures

A company can use HDD and CDD futures contracts traded on the CME to hedge their weather risk exposure. These contracts trade like other futures but are "priced" based on degree day indexes. Futures traded on the CME can be either bought or sold. If a company buys a monthly weather futures contract, the more degree days in the month, the greater the value of the futures contract. A company will buy the futures contract at a degree day index level traded in the market. If the number of degree days in the month turns out to be higher than the index level where the contract was bought, the buyer gains on the futures contract. In a similar manner, a company can sell a HDD or CDD monthly weather futures contract. If the number of degree days in the month is lower than the index level where the contract was sold, the seller gains on the futures contract.

Suppose a wheat farmer wishes to hedge the event of an extremely cold winter, she can buy an HDD contract. If the weather is unusually cold, she will receive payment from the futures position because the HDD index went up, (i.e. there were more HDDs in the colder month). However, if the weather is only mildly cold, she will likely harvest a large crop of wheat and earn favorable revenues but lose money on the futures position, which can be offset by the revenues from the larger crop. In the same way as HDD futures, CDD futures can be used to hedge the risk of decreased revenues when the weather is extremely hot. For example, if a corn farmer wishes to hedge his risk that the summer will be extremely hot, he can buy CDD futures contracts. If the summer is indeed hot and his corn crop does poorly, the value of the CDD futures contracts will increase and offset the loss of revenue from a bad crop.

However, if the summer is mild and his crop does well, he can offset the loss on the CDD contract with the additional revenue from his corn crop.

Taking the other side of these contracts, suppose a company wishes to hedge a mild winter or summer, it could sell HDD or CDD futures contracts. For example a utility company experiences reduced revenue when the winter weather is mild. The utility can sell an HDD futures contract and, if the winter is mild, collect a gain in its futures position because the HDD index would move down (i.e. there would be fewer HDDs in the month). However, if the winter turned out to be extremely cold, the utility's revenues would increase, but the company would realize a loss in the futures position, which would be offset by the increase in revenue. As in any hedging case, weather futures can be used to "lock-in" the revenue that a company might forgo if the weather is unfavorable to its profit.

Entering into a CME weather futures contract is essentially like entering into a swap based upon the weather, only clearing through the CME Clearing House. The two parties essentially swap payments based on the weather; one party is paid if the weather is relatively extreme and the other party is paid if the weather is relatively mild. For example, suppose that the utility in the previous example wishes to hedge its potential loss of revenue due to a mild summer in Des Moines, Iowa. The utility could enter into a short July CDD futures position (sell the CDD contract) for Des Moines at a CDD index "price" of 850. If the CDD in July were lower than 850, hence cooler days and less need for power to run air conditioners, the utility would gain from the futures position. Now suppose that a corn farming company took the opposite long position in the same futures contract (bought the CDD contract) at 850. The farming company loses revenue if the summer is too warm and burns up the corn crop, so it wishes to hedge against this risk. At the end of July, if the CDD for the month were 950, the utility would pay to the Clearing House $2,000 ($20 * 100) and the farming company would receive $2,000.

Hedging With Weather Options

The options that the CME offers on HDD and CDD futures contracts add the aspect of limited risk to the extensive market coverage offered by futures. The buyer of a weather option has theoretically unlimited profit potential on the upside, while only risking the premium paid for the option on the downside. This limited downside risk is transferred to the writer of the option, who accepts potentially unlimited downside risk in return for receiving the option premium at the time of the sale. Weather options derive their value based on a strike price, which is indexed as the number of degree days in a period. If a company wishes to hedge the risk of a period of extreme weather (i.e. wanted to gain if there were more degree days in a given month), they would buy a call option with a strike price equal to the number of degree days above which they wanted to realize a gain. The higher the strike number of degree days, the cheaper the option, but the more degree days in the period would have to accumulate for the company to realize a gain on the option position. This call option would increase in value as the number of HDD or CDD in a period increased above the strike price. If a company wishes to hedge the risk of a period with mild weather, they would buy a put option at the desired strike price. The put option would have a greater value the more the cumulative number of degree days in the period was below the strike price.

CME options on HDD and CDD futures are European style, which means that they cannot be exercised before their respective expiration dates. The underlying instrument for each HDD or CDD option is one HDD or CDD futures contract. Like weather futures, a weather option contract is worth $20 times the premium or price of the option. For example, a quote of 3.00 on an HDD or CDD option represents a premium of $60, or 3 price ticks. For example, if the underlying July 2006 CDD futures for the city of Atlanta are trading at 800, and an "at-the-money" CDD call with a strike price of 800 is trading at 10.00, the call would have a value of $200 ($20 x 10 CDD Index points), whereas an "out-of-the-money" 830 CDD call might have a value of 5.00 or $100 ($20 x 5.00 CDD Index points).

If a farmer wanted to have protection from an extremely cold winter or hot summer, he could buy HDD call options, in the case of winter, or CDD call options, for summer. For example, if a wheat farmer wanted to use options to hedge his cold weather risk, he could buy January HDD call options for the city of Kansas City, Kansas at a strike of 450 HDD. The call options would be worth $20 times each HDD above 450. Thus, the farmer would receive payment if the weather were extremely cold and his wheat froze but would only lose the premium paid for the call

options if the winter was mild and the option expired out-of-the-money (i.e. the HDD index was below 450). In much the same manner, a corn farmer could hedge his warm weather risk on his corn by buying CDD calls for July. If the cumulative CDD for the month of July were above the strike price of his calls, the farmer would realize a gain on the calls; otherwise he would only lose the premium paid for the calls.

Weather options can also be used to hedge against the risk of insufficient GDD, or mild weather, in a period. While HDD and CDD calls can hedge against extreme winter or summer conditions, a farmer can buy weather put options to protect against the risk that the crop does not have good enough weather conditions to sufficiently produce. For example, suppose corn needed 3,000 GDD to produce and the farmer expects these GDD to accumulate over 120 days. These 3,000 GDD, with a base temperature of 50 degrees, over this time period equal 1,200 CDD. The farmer could buy CDD put options over the season with a strike price of 1,200 CDD and would gain $20 on each put option for every degree day that the CDD index was below 1,200. He would only lose the premium paid for the options if the weather was warmer but his corn would produce and provide greater revenue to cover the option premium.

UNIQUE ASPECTS OF WEATHER DERIVATIVES

Weather futures and options offered on the CME have similar characteristics to futures and options written on other types of assets. However, weather contracts have a number of characteristics that are unique. One unique aspect about the products traded on the CME is the ability of hedgers to construct seasonal weather contracts. Since weather derivatives were initially launched, the CME has expanded their product offering, and now offers contracts on entire seasons. Another unique aspect of weather derivatives is the ability of a company to hedge volumetric risk. Volumetric risk is the risk that a company cannot sell the volume required to generate a sufficient profit even though it is able to get the price that it may desire for its product. For example, a farmer might sell his crop at a good price, but due to the weather, he may not be able to harvest sufficient volume. A third aspect of these contracts, that hedgers must be aware of, is basis risk. Basis risk is not unique to weather derivatives but since these contracts depend on the weather, understanding the nature of weather related basis risk is of particular importance.

Alternative Contract Terms

In addition to futures and options, the CME offers HDD and CDD seasonal contracts that allow hedgers or speculators to buy or sell a single contract that covers an entire season. These seasonal contracts are structured like futures, only that the HDD or CDD "strike" is set for the entire season rather than a single month. The exchange trades a fixed HDD seasonal contract that covers the months of November through March and expires in March of each year. In the fourth quarter of 2005, the CME began to allow traders to create "customized seasons" HDD and CDD seasonal strips. These strips allow market participants to choose the consecutive months in a season that they wish to hedge, from two to seven consecutive months. The CME's seasonal HDD strips cover October through April, with contracts that begin in the months of October through March. The CME's seasonal CDD strips cover the months of April through September, allowing investors to hedge from two to six consecutive months.

As an alternative to the seasonal strips, a company can purchase separate options of HDD or CDD contracts for each month in the season to be hedged. These individual options are similar to a strip but are structured so that each month in the season has a separate strike price. The advantage of purchasing multiple options, rather than a single, longer-term strip covering several months, is that the options may be broken into monthly contracts. The individual options, with the different strike prices, can be better tailored to the revenue pattern of the company constructing the hedge. The disadvantage to using multiple options, over a strip, is that the options, when purchased individually, often cost more than a strip covering the same time period. The hedger must decide whether this extra cost is worth the risk of having a single HDD or CDD strike price set in the strip.

Hedging Volumetric Risk

A great advantage of weather derivatives is that they can be used to hedge an aspect of risk not often able to be hedged, volumetric risk. Many businesses are exposed to various types of risks, some of which are harder to hedge than others. Weather derivatives can be used to hedge volumetric risk as opposed to price risk. A farmer will not

produce as much grain in times when the weather is damaging to his crops, thus he can use weather derivatives to hedge his yield risk, as opposed to his price risk. Agricultural companies have many ways to hedge price risk, but these methods continue to leave the company exposed to low yield. Months of high HDD or CDD (extreme temperatures) can lower the yield of crops and squeeze a farmer's revenue even if he has hedged his price risk properly. For example, if a corn farmer is concerned with the potential of a large loss in revenue when the summer is hot, she could buy CDD futures or buy CDD calls. If the summer is hot and she produces a low corn yield, the revenue gained from the CDD weather derivatives will offset the loss from the lower yield.

Agricultural companies often experience a squeeze on profits if a month is unseasonably mild. If the weather is mild, a farmer may have still have a relatively low yield due to less than peak growing conditions or insufficient GDD. In contrast, during times of mild temperatures, when the crop does produce well, a farming company's revenue will be capped by the event that an acre can only yield a given amount of crop. These events can also be hedged using weather options. To hedge against a mild summer, a farming company can buy CDD puts with a strike price at the CDD index level at which the company expects it may hit a peak in yield or begin to have a lower yield. If the weather does turn out to be mild and the cumulative CDD for the period turn out to be lower than the strike price of the put, the gain from the put will offset the lack of additional crop or the lower yield due to less than perfect temperatures and add to the revenue of the company.

Basis Risk

The over-the-counter weather derivatives market includes most U.S. cities because the derivatives are fitted to the needs of the individual buyers or sellers. However, the CME market only includes the cities listed on the exchange, which means that a company wishing to hedge weather for cities not listed by the CME face basis risk, or risk that arises when value of the asset used to hedge does not exactly equal the value of the asset being hedged. For weather derivatives, basis risk arises when the weather in one area does not exactly equal the weather used to value the futures or options contract. Agricultural risk managers must be aware of the basis risk inherent in the weather derivatives market. Basis risk can be substantial in this market. The fact that the weather can be totally different in two relatively close locations, leads to a potentially high amount of basis risk. The information used to settle the weather contracts is gathered from equipment located at the end of airport runways in each respective city. Due to geographic surroundings of a city, the weather of one area in a city for which a weather contract is written may differ from the "price" of the contract itself. Thus, some basis risk may even exist in a hedge where a weather derivative is used to hedge weather in a different part of a city from where the temperature is recorded.

Basis risk is largest in weather hedges where the hedger wishes to hedge the weather exposure in a city other than the city on which the weather contract is written. For example, if a farming company wanted to hedge its weather risk in Waterloo, Iowa using CME futures, it would have to use futures on the weather in Des Moines, which would lead to basis risk. Basis can often be traded in the over-the-counter market by writing a contract on the difference in the HDDs or CDDs between two cities. Numerous weather factors influence the correlation, which changes over time, between the HDDs and CDDs in two locations. Basis risk must be realized when a hedge is put on and monitored so that it does not get out of control. Even though the basis risk of a weather hedge may be large, the greater certainty of a firm's revenue is typically worth the basis risk taken, and the basis risk is usually never greater than the risk of an unhedged position where weather derivatives are not used.

CONCLUSIONS

According to the CME, weather derivatives are currently the fastest growing derivatives market (Chicago, 2006). Utility companies have been the largest end-users of weather derivatives. Yet, there is much more historical data available for the agriculture markets than for utilities. As a result, the use of weather derivatives to hedge agricultural commodities and livestock is increasing. Weather futures contracts could be easily used to hedge much of the risk in agricultural commodity volume and in turn lead to increased revenues for farmers and others in agricultural related businesses.

Regardless of the specific type of risk to be hedged, weather derivatives are being used at an increasing rate. The CME notes that it is estimated that almost twenty percent of the U.S. economy is in some way affected by the weather (Chicago, 2006), which shows that there is evidently a need for some type of financial protection from weather related losses. Weather derivatives offer that protection. The introduction of weather derivatives gives industries with revenues that are temperature sensitive the ability to manage the risk of unfavorable temperature movements and allows them to be in better positions to service their customers and grow their respective businesses.

SUGGESTIONS FOR FUTURE RESEARCH

Future research may examine how weather derivatives are currently being used, by whom, and in what part(s) of the United States or the world. Other research may focus on the specifics of basis risk, how this risk can be best hedged, the specific financial implications of basis risk to those that trade weather derivatives, and how this risk can be valued. Still other research may look at applications of weather derivatives, other than in utility and agricultural industries.

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